COMPARISON OF LATITUDE OBSERVATIONS AT SAYRE OBSERVATORY, SOUTH BETHLEHEM, AND AT FLOWER OBSERVATORY, PHILADELPHIA,

FROM SEPTEMBER 30, 1904, TO SEPTEMBER 3, 1906.

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(*Read April 20, 1907.*)

This paper is based on two years work on latitude determination at Bethlehem compared with that obtained during the same period at Flower Observatory, the results of which Professor Doolittle has kindly furnished me in advance of publication.

The Sayre Observatory at South Bethlehem, under Professor Doolittle's direction, was among the first to be devoted to this class of work and the observations, continuing through a period of nearly twenty years, resulted in a series which has been an invaluable aid in the discussions of the laws of the variation of latitude. It was thought that a continuation of the same class of work for some years might be desirable as it would result in a longer series at a given point than could be found elsewhere.

To aid in this project, the late Mr. Robert H. Sayre, one of the trustees of Lehigh University, furnished the means for procuring a modern zenith telescope and a suitable house for it.

The zenith telescope house was erected in the spring of 1904 according to plans which conform to those of the International Latitude Stations and is composed of wood excepting the roof which is of tin. The walls are double, with an air space of one foot between the inside ceiling and the latticed exterior. The inside dimensions are, 10 feet square with walls 7 feet high. The roof is divided in the middle and the two halves move on pinions giving a maximum opening of 6 feet. The object glass of the telescope, when pointing to the zenith, is about 2 inches below the top line of the walls.

The pier is composed of concrete, the top face being 27 inches square, and rises from a foundation of the same material in the form of a cube whose dimensions are 5 feet, placed wholly beneath the surface of the ground.

The zenith telescope is from the work-shop of Warner and Swasey, the optical parts by Brashear. The clear aperture of the object glass is 4½ inches, its focal length 48 inches and is furnished with electric illumination. The base and vertical axis are of massive construction. It maintains its position in adjustment with little variation. A magnifying power of 144 has been employed throughout. No record of errors in azimuth, collimation and level has been kept. The sum of these corrections for any star of the observing list during the period embraced by these observations was always less than one second of time.

The observations were made with a view of determining a value for *the Constant of Aberration* according to the plan suggested by Dr. Küstner of Berlin. This entails the grouping of the greater part of the observations around four periods in the year which include about eight months altogether, but their distribution is such that the results are equally available for investigating the variation of latitude. The method of conducting the observations has been identical with that followed at Flower Observatory. Since the two stations are practically on the same meridian and the declinations of the stars are eliminated, the two series are directly comparable.

At Bethlehem the list of stars comprise 4 groups of 10 pairs each and the usual adjustment of each observed latitude to the mean latitude which would result from the average of the 80 stars declinations have been made. Observations for investigating the effect of temperature on the micrometer value were made by two methods and the final results for the temperature coefficient for the two years are in such close agreement as to inspire some confidence in their trustworthiness. These values for the two years, in units of the sixth decimal place are 146 and 138. The individual determinations are so discordant, however, that I have not considered their introduction into the reductions advisable, since the average correction for the micrometer for any group of stars is less than one

revolution. The probable error of latitude from one pair of stars —the part due to observation alone—for the two years was ± 0″.121 and ± 0″.112 respectively.

The following work is an attempt to find whether the abrupt deviation at irregular intervals of the observed latitude from the mean value by an amount many times its probable error at *Bethlehem* is duplicated in a greater or less degree at *Philadelphia.*

Thus, at Bethlehem the observations gave for the ten pairs

	40° 36′ 20″ +				
May 21, 1906	3″.58	3″.54	3″.56	3″.74	3″.80
On next observing night	3 .88	3 .83	3 .92	3 .74	3 .94
The differences	+0 .30	+.29	+.36	+00	+.14

					Mean
3″.60	3″.78	3″.74	3″.75	3″.74	**3″.68**
3 .99	3 .84	4 .12	3 .82	4 .10	**3 .92**
+.39	+.06	+.38	+.07	+.36	**+.24**

The first values give a latitude agreeing closely with the finally deduced value for that date; therefore the difference, 0″.24 represents a departure from the mean of 7 times the probable error.

By applying the average difference between the two stations to the latitude at Philadelphia we can construct a diagram which very nearly represents the efforts of two independent observers to follow the motion of the pole at a given meridian. (Page 170.)

The observations at each place for any day on which no corresponding observations at the other place were made have been omitted so that the diagrams represent about half the observations at Philadelphia and two-thirds those at Bethlehem.

The two curves agree pretty closely as to the lengths of the periods and total variation, but the maximum and minimum values at Philadelphia fall about three weeks earlier than the corresponding phases at Bethlehem.

Two methods will be employed in the comparisons.

First Method.

The observations were divided into periods of about forty days each and the means of the latitude for each of these periods found. The simple difference was taken between the latitude for each group

and the mean of the corresponding forty day group in which it is found and the result for each station tabulated side by side.

Omitting all record of groups where the observations were less than 4, there remian for comparison 209 groups which give the following results.

Cases where one or the other residual was zero $= 27$.
Cases where both residuals were greater than $0''.15 =$ None.
Cases where both greater than $0''.10 = 10$: — 7 "like," 3 "unlike."
Cases where smaller residual was $> 0''.05$ and $< 0''.10 = 62$: — 35 "like," 27 "unlike."
Cases where smaller residual was between $0''.00$ and $0''.05 = 109$: — 54 "like," 55 "unlike."

An actual departure at both places from the mean latitude in the same direction should manifest itself in the majority of cases by an agreement of sing in these residuals. This is actually found in the case of the residuals greater than $0''.10$ but the total number of cases is too small to have much weight. Irrespective of the magnitude of the residuals there are 96 "alike" and 85 "unlike." If the two series of observations were entirely independent the theory of probability would require that the number of "like" and "unlike" be 90 each and the difference between this and the actual numbers is so small the inevitable conclusion follows that the two series are practically independent.

Second Method.

Excluding all work in which a determination at either place on any night depends on the observations of less than six pairs there remain 123 common dates which represent 3,410 separate determinations, 1,730 at Philadelphia and 1,680 at Bethlehem. By constructing to a generous scale the diagram just shown on the screen and drawing smooth curves for the two sets of observed latitudes we may consider these curves as the actual values of the latitude during the period represented in this comparison and the differences between the latitudes at each station and the value derived from the curve will give us a set of residuals which should be a measure of the precision of one night's work on the supposition that the variation is represented by long periods.

Let ΣV_1^2 and ΣV_2^2 be the sum of the squares of the residuals at Philadelphia and Bethlehem respectively. Evidence of systematic fluctuations would be shown if $\Sigma V_1^2 + \Sigma V_2^2$ is appreciably greater than ΣV_3^2 where ΣV_3^2 is the sum of the squares of the residuals derived directly from the differences of the observed latitudes.

These last residuals must be derived in a way that will eliminate the systematic divergence resulting from an apparent constant difference in the times of maxima and minima at the two places. This has been effected by considering V_3 as the algebraic difference between V_1 and V_2. Without reproducing the details the following results were found.

$$\Sigma V_1^2 = 0''.5706$$
$$\Sigma V_2^2 = 0\ .6993$$
$$\Sigma V_3^2 = 1\ .2718$$

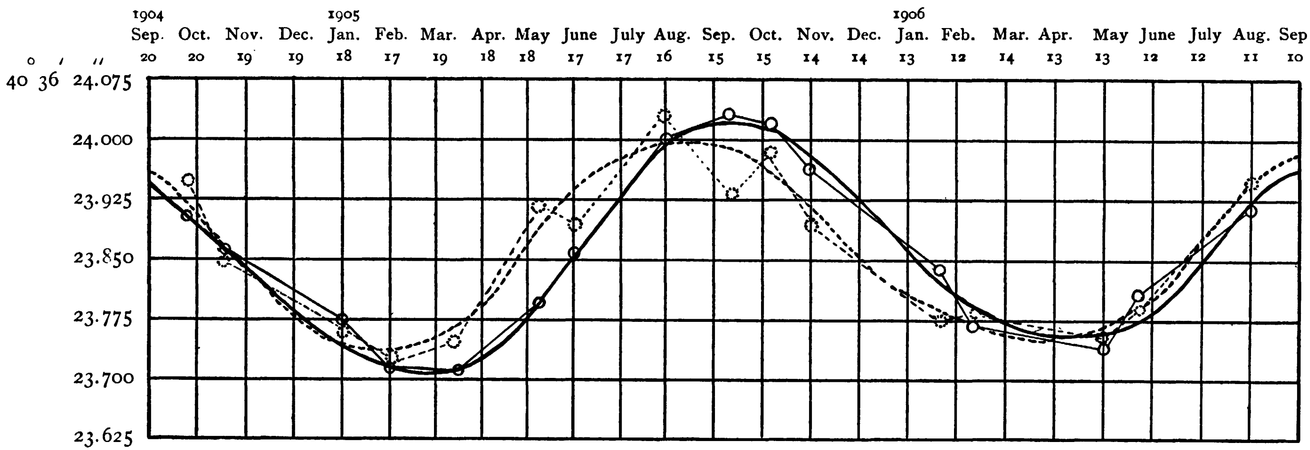
Since $\Sigma V_1^2 + \Sigma V_2^2$ differs from ΣV_3^2 by less than $0''.002$ it is evident that these observations show no relation between abnormal values of observed latitude at the two stations.

If the residuals are reduced to probable error there results:

For one night's determination from 10 pairs—

at Philadelphia $\pm 0''.053$: For one pair $\pm 0''.17$.
at Bethlehem $\pm 0\ .057$: For one pair $\pm 0\ .18$.

The part in this latter due to observation alone was nearly $\pm 0''.12$ leaving $\begin{matrix}\pm 0''.13 \\ \pm 0\ .14\end{matrix}$ at the two places for the probable error of one observation which is apparently beyond the observer's influence.



Graphical representation of the variation of latitude as observed at the Flower Observatory, Philadelphia, and the Sayre Observatory, South Bethlehem.

NOTE.—The latitudes of Flower Observatory have been increased by 38′ 21″.744, the mean difference in latitude between the stations.

Dotted curve.—Philadelphia.

Full curve.—South Bethlehem.